On-line Identification of faults in Solar PV Panels using Soft Computing Techniques

Synopsis

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Submitted by

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Introduction

The Population's well-being and economic development can't imagine without Electric energy. Energy resources are interlinked with population development & world economy. Increasing demand and required production are more concern to shift in renewable due to oil crises, like1970s. The selection of energy sources that should be utilized depends on a few important aspects, such as ecology, safety, and economics. Therefore, a solar segment of renewable energy is regarded as an alternative source, considering the potential of exploring sustainability with the least harm to the environment.

Indian tropical climate & high solar irradiance availability assist in the harvesting of solar energy in India. Due to long hours of sun availability with high solar intensity per day, it is possible to utilize the big potential of the solar segment as a future energy source. By the end of 2022 Solar installed capacity is about 100GW 2022 in India[20]. The partial fulfillment of the mission of clean emission-free production and continuous supply during day time possible to be achieved by Solar energy. However, the efficiency of energy conversion of photovoltaic cells depends on awareness of operational aspects also. Various factors like weather conditions and locations, impact on energy production of a Solar Photovoltaic system. Outdoor field analysis & review of the installed plant on a performance basis can result in potential improvement in upcoming technology of the solar PV systems.

It is even more critical to understand the performance and reliability of photovoltaic (PV) plants, considering the fast expansion of such systems. The generation of a number of units and the payback period of the PV plant depends on the electrical performance of the PV module and also on its operational lifetime. JNNSM – Jawaharlal Nehru Solar Mission launched from 2012-2022 to contribute to grid-connected solar power on reducing costs for achieving various objectives[4]. The correct investment decisions and a better regulatory framework and favorable government policies are based on the performance of the solar power plant's objectives. The reason of the deterioration in the electrical performance of PV modules included Cells' low efficiency, changing weather causing discontinuity of solar source, and electrical mismatch effects due to field & physical condition. The nonlinear current-voltage characteristics make it difficult to predict modeling or solar cell performance in shading conditions.

Environment, a cause of faults on solar PV panel

Uneven illumination on the solar PV surface due to shadows developed through different obstacles like other panels/modules, clouds, buildings, etc. It results in a large change in maximum power. Under extreme cases of shading, reverse bias on the solar cell might exceed its breakdown voltage and cause irreparable damage. The hot-spot formation in the individual shaded cells is the result of power losses, local heating, and thermal stress. It must focus on the critical issue of shading because it is related to performance, Consumption of power by solar cells instead of generating power during reverse biased resulting in a loss of total output power. Local heating due to power losses and a rise in the temperature is observed in the individual shaded cells. This is one of the causes, affecting surrounding cells. The rise in temperature causes thermal stress on the entire module and causes local defects. That may result in failure in the entire array. Bypass diodes is an economical & simple method to manage the shadow possibility. It is important to address the consequences of shading & the economic operation of PV module. Ambient temperature also play key role during operation of PV plants. Following fig.1 shows the Environment, a cause of faults on solar PV panel and fig.2 BPD operation as a result of shading

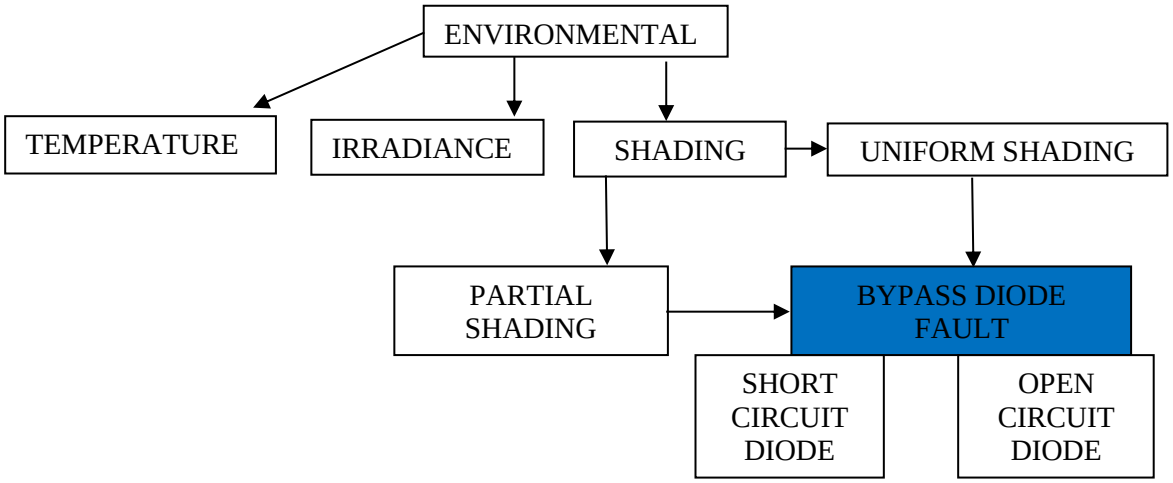

Fig. 1 Environment, a cause of faults on solar PV panel

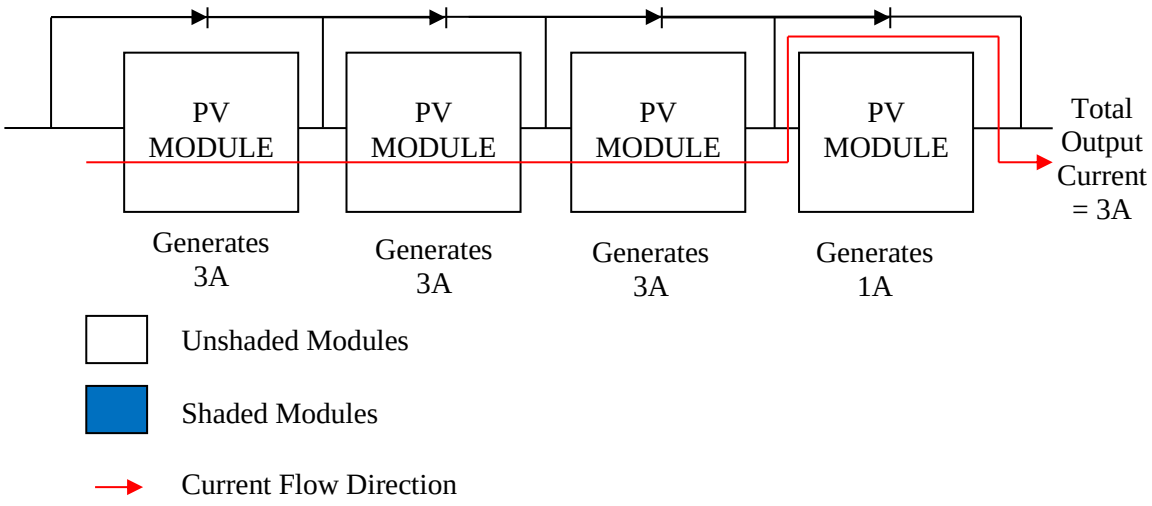

Fig. 2 BPD operation as a result of shading

Series arc generation in a PV module can be prevented by the use of a bypass diode at the cost of a significant reduction in the performance of a PV module. The shaded cell's very high reverse negative voltage is restricted by bypass diode forward-bias voltage, such that the maximum reverse voltage across that row is equal to that of the forward-bias voltage diode.

A significant number of bypass diodes in PV system failures have been reported in midlife as shown in the picture, and thereby, bypass diodes integration is one of the main focus areas or concerns for the productive & healthy operation of PV modules [31].

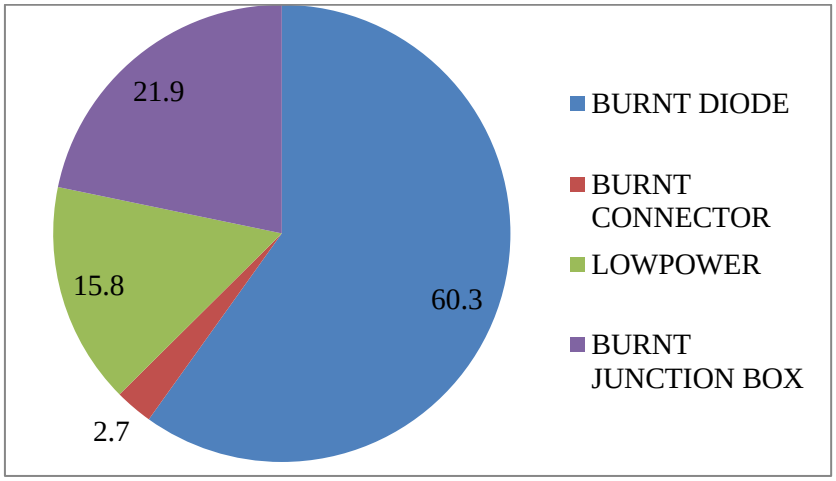

Fig. 3 Relative failure analysis of PV module

Long-term power dissipation in the bypass diode increases the junction temperature of the bypass diode & junction box due to any mismatch or partial shading, as well as a rise in the temperature of PV cells adjacent to the junction box. These cumulative effects could lead to the failure of high resistive solder

bonds that interconnect cells and contact ribbons, insulation burn of the cables and junction box encapsulation, and hotspot formation.

Literature review

Most electrical-based FDD methods rely on some type of PVS model to detect various types of faults. Electrical methods can be also classified into five groups : statistical and signal processing approaches (SSPA),I-V characteristics analysis (I-VCA),power losses analysis (PLA),voltage and current measurement (VCM),artificial intelligence techniques (AIT).[53]

Bypass diodes placed in the junction boxes observed a temperature hike of around 155 to 190 ºC during shading time in the field, where the surrounding temperature is often 30-40 ºC and 40 ºC or more difference in module temperature and ambient.[30]. According to another research group closed fitting or junction box is designed so that it prevents the end connecting electrode of the module and bypass diodes from aging due to the environment. The heat developed from the working solar cells in the PV module is not well dissipated to the outside. The temperature rises to over 70 °C on sunny summer days and It was noticed that the bypass diode work at over 60 °C for 70 h or more in a year inside the junction box The leakage current of a bypass diode under reverse bias increases, Under such extreme operating conditions, In such conditions,35 times higher leakage current was observed as compared to that measured at 25 °C and it contributes to thermal runaway and failure of the bypass diode. [2].

A new method is proposed with the non-invasive method to estimate the $I_{sat,db,}$ and η_{db} of the bypass diodes present in a PV module using two experimental I-V curves. Initially, I-V curve is taken with a full covering of the sub-module of the module whose BD will be parameterized; while the other I-V curve is taken without any shadow on the module. From those curves, The I-V curve of the bypass diode is estimated and η_{db}, $I_{sat,db}$are calculated by solving a system of two nonlinear equations[21]

A new approach to analyzing power losses with the model, mainly due to mismatch effects, in a PV system, is presented. The developed model was used to extract the main PV module parameters and the reproduction of I-V characteristics. This method allows the Photo Voltaic system's dynamic behavior to be replicated with real ground conditions of work. The study associated with a mismatch between PV modules forming the PV array results in 10% Power losses [15].

It focuses on the mono-crystalline PV module technology subjected to operating conditions with some

cells partially or fully shaded. A shaded cell under hot-spot conditions operating at reverse bias is dissipating power instead of delivering power. A thermal model allows analyzing the temperature increase as a cause of the shaded cells of the module under a hot-spot condition with or without protection by a bypass diode [27] .

The most common is to place a diode anti-parallel to the PV cells or a substring of cells. If the current generated by one cell becomes smaller than other cells, the current flow will find the bypass diode path. Therefore, the topology of bypass diodes and the PV array arrangement can affect the possibility of hotspot failure. The impact of the hot spot in PV modules is significant since it may reduce the output power generated by the group of cells under the same bypass diode to zero [9].

The failure of the bypass diode can be explained in two separate modes: short circuit or open circuit of the bypass diode. A short circuit failure of the bypass diode can result in the Shunting of healthy PV cells is the result of short circuit of BPD in the module. It will seriously impact the performance of the PV module. An open circuit of the bypass diode again influences on the generation during shading & increases the chance of Hotspots. Reduction in the generated output power of PV modules by shading and consequent reliability-related issues such as hotspots have been studied. But, this work does not provide much information on the reliability of bypass diodes. [16].

This paper[19] focused on a Simulink model, it functions on an array's mathematical equations derived for solar cells and develops with common blocks in Simulinklibrary. Physical parameters i.e shunt resistance Rsh, series resistance R_s of the cell, saturation current & quality factor of diode calculated with consideration the effect of environmental conditions (solar insolation and temperature).

Another study Intervened about the module design with bypass diodes. According to it maximum of 20 cells can be protected by a single bypass diode to prevent overheating as a result of partial shading. [18]

Combined model of bypass diode and PV module

Part-1:-

In the one-diode model, detailed parameters for the different manufacturers are available for different PV modules in the market. So it is considered to simulate with one diode model in place of the double-diode model. In fault analysis one-diode model is used for accurate results with different PV modules. PV module is assumed as a basic unit consisting of identical solar cells. So, modeling and simulation of

PV modules become key steps to analysis.

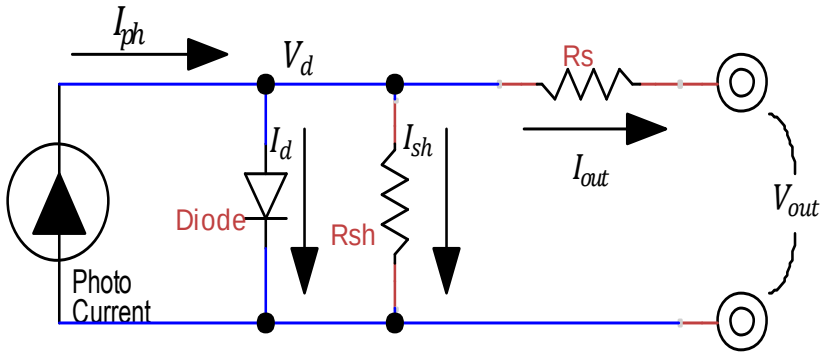

Fig. 4 PV model of Cell using Single diode

Abovecircuit is considered to develop model equations. According tothe number of cells(n) the Schockley diode equation is modified, for the PV array,I_d is used to define the diode current.

Modified equation (Schockley diode equation) $I_d = I_{rsat}\left(e^{\frac{qV_d}{nmkT}} - 1\right)$ (1)

The voltage across the diode is: $V_d = V_{out} - I_{out}R_s$ (2)

The current in the shunt resistance is: $I_{sh} = \frac{V_{out} - I_{out}R_s}{R_{sh}}$ (3)

The output current is: $I_{out} = I_{ph} - I_d - I_{sh}$ (4)

On Substitution :$I_{out} = I_{ph} - I_{rsat}\left(e^{\frac{q(V_{out} - I_{out}R_s)}{nmkT}} - 1\right) - \frac{V_{out} - I_{out}R_s}{R_{sh}}$ (5)

Part-2:- Modeling of By Pass diode integrated with PV module

To protect PV modules from negative voltages, bypass diodes are needed in Photovoltaic (PV) systems. They prevent the degradation of a PV plant under partial-shading conditions in terms of changes in the output power of the PV array in presence of bypass diodes. So, need to work on a modified bypass diode model is essential for estimating the power loss which is an important parameter to analyze the cause of the failure of BPD. The above equations can be written in modified form to analyze bypass diode failure.

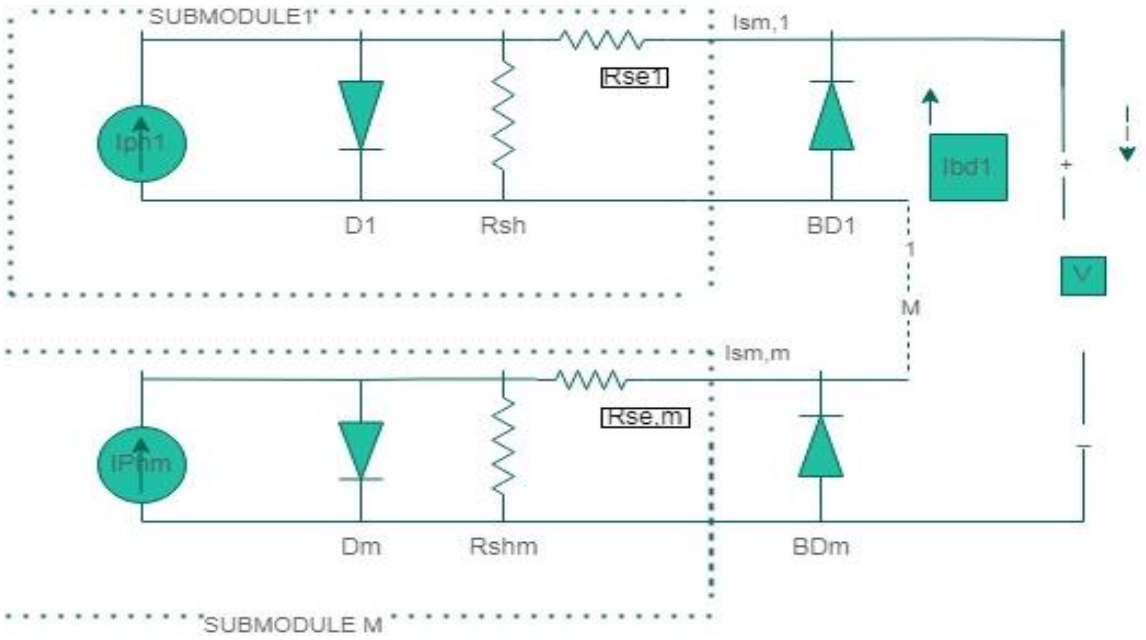

Fig. 5 Modeling of By Pass diode integrated with PV modules [21]

$$I_{out} = I_{ph} - I_{rsat}\left(\exp^{\frac{(V+q(I-Idb).R_S)}{nmkT}} - 1\right) - V_{out} + (I - Idb)\frac{Rs}{Rp} + Idb \qquad (6)$$

Where $I_{db} = \quad I_{rsatdb}\left(\exp^{\left(\frac{-V}{nmkT}\right)} - 1\right)$

I_{rsat}: Diode Reverse Saturation Current (μA),

$I_{ph:}$ Cell photo generated current.

R_s and R_{sh} series resistances and intrinsic shunt of the cell respectively.

T: operating temperature (K); Ir: solar irradiation (W/m^2).

q: electron charge, = 1.6×10^{-19}C;

V_{oc}: open circuit voltage (V),

N_s: number of cells connected in series;

Ŋ : the ideality factor of the diode;

k: Boltzmann's constant:1.3805×10^{-23} J/K.

I_0 : saturation current,

V_t: diode thermal voltage (V).

$E_{g0:}$ is the band gap energy for silicon = 1.1 Ev,

$k_{i:}$ Short-Circuit Current temperature coefficient,

k_v : Open-Circuit Voltage temperature coefficient,

To generate electricity from PV generation systems PV arrays are used. PV arrays are a combination of PV modules and these modules are connected in series or parallel according to output needs. These modules consist of PV cells series-parallel connections. The I-V characteristics and unique maximum power point (MPP) are defined for every module, string, and the whole array, whether in normal or shade conditions. The V-I curve is determined by the interactions among them when P-V modules are connected in a different configuration. Fundamental approaches to PV system power loss analysis are based on I-V characteristic analysis, with an understanding of the MPPT algorithm

Research Gaps

It is noticed [31,9,10,14] that permanent reduction of the PV module output in operation conditions is still challenging due to BPD faults condition arise. Need to differentiate this situation first, to improve performance in terms of reduction power loss and by pass diode failure in field. It Prevent further increase in Hot spot in PV installation.

Proposed work:

It is propose to develop an Electrical Model of PV modules with a bypass diode for normal & faulty condition. This used to get various parameters

Results will be observed in MATLAB Simulink .

This model will be utilize for field data of the PV module to get more accurate predictions of BPD failure analysis for above two sets of conditions

I-V characteristics analysis (I-V), power losses analysis (PLA), voltage and current measurement (VCM) for fault detection. The designated technique is based on anomalies appearing in I-V curve of PV module.

Objectives

- Develop a model for solar PV panels and simulate it under different conditions.
- Development of data acquisition system for a proposed model to validate.
- Development of integrated soft computing technique for fault identification like BPD failure

Table 1 Time line

Phase-1: Task List (Year-I)	
Period	Major Tasks
0-1 Month	Topic Finalization
1-3 Months	Collection of last 10 years articles from Elsevier, Sp, IEEE on my topic
3-4 Month	Frame the detailed sketch of the research gaps
4-4.5 Months	Problem Identification
Phase 2: Task List (Year-II)	
1-2 months	Literature survey
0-1 month	Establish the analysis of the existing works
1-3 months	Differentiate the existing methods and the necessity for developing new model
	Analyze the achievements of the existing methods
4.5 - 5 Months	Propose a research solution
Phase 3: Task List (Year-III)	
5 - 6 months	Learn about the implementation tool and implementation
6 - 9 months	Implement the research solution to solve the challenges of the existing methods
9 - 10 months	Implement the existing/comparative methods
10 - 10.5 months	Analyze the performance of the proposed model based on the performance metrics
10.5 - 11 months	Perform the comparative analysis of the existing methods with respect to the proposed model
11 - 12 months	Establish the final achievement of the proposed model
0 - 1 month	Documentation
6 - 12 months	Publication process

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